IS 397-2 (2003): Method for Statistical Quality Control During Production, Part 2: Control Charts for Attributes [MSD 3: Statistical Methods for Quality and Reliability]

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भारतीय मानक

उत्पादन के दौरान गुणता नियंत्रण की प्रणाली

भाग 2 गुणों और दोषों की गणना के लिये नियंत्रण सारणी

(तीसरा पुनरीक्षण)

Indian Standard

METHODS FOR STATISTICAL QUALITY CONTROL DURING PRODUCTION

PART 2 CONTROL CHARTS FOR ATTRIBUTES

(Third Revision)

ICS 03.120.30

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FOREWORD

This Indian Standard (Part 2) (Third Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by Statistical Methods for Quality and Reliability Sectional Committee, had been approved by Management and Systems Division Council.

There are many situations where the quality characteristic can be observed only as an attribute, that is, by classifying each item inspected into one of the two classes as either conforming or non-conforming. This is especially so in the case of some quality characteristics like colour and surface finish, blowholes, cracks, damages. Even in the case of some quality characteristics, such as, dimensions, which can be checked by using 'go', 'no go' gauges result in the attributes type of data. In all such situations when the item under inspection can either be classified as conforming or non-conforming or when the number of non-conformities on an item could be counted, control charts by attributes is more relevant. This standard has been prepared to meet the growing demand for the widespread use of the control charts by attributes.

Apart from the cost considerations, the control charts by attributes have some other advantages over the control charts by variables. Whereas in the latter case each quality characteristic has to be controlled with the help of separate set of control charts (usually the mean and the range chart), an attribute control chart like the one for fraction non-conforming may be made applicable to any number of characteristics as long as the result of an inspection is classification of item as conforming or non-conforming. In addition, the control charts for fraction non-conforming provides the management with a useful record of quality history and changes that occur in the quality level from time to time. It should, however, be recognized that the control charts by attributes require normally substantially larger sample sizes than the control charts by variables in order to maintain the same level of sensitivity to shifts in the process.

Since the basic philosophy for the use of control charts in manufacturing operations remain unaltered whether the characteristic chosen for control is of the variables or attributes type, this part is a necessary adjunct to Part 1 of the standard. Whenever the basic principles are the same they have not been repeated in this part.

This standard was originally issued in 1952 and revised in 1975 and 1985. In view of the experience gained with the use of this standard in course of years, it was felt necessary to revise it again so as to make the concepts more up to date. Further the following changes have been made in this revision:

a) Demerit control chart has been excluded from this standard, as the same is now included in IS 397 (Part 4).
b) Annex B has been modified to include more calculated values of *UCL* and *LCL* for fraction non-conforming chart.
c) Example for non-conformities per item has been modified.
d) Many editorial mistakes have been corrected.

In addition to this Part, IS 397 has the following four parts:

IS No.	*Title*
397	Methods for statistical quality control during production:
(Part 0) : 2003	Guidelines for selection of control charts (*first revision*)
(Part 1) : 2003	Control charts for variables (*second revision*)
(Part 3) : 2003	Special control charts by variables (*first revision*)
(Part 4) : 2003	Special control charts by attributes (*first revision*)

The composition of the Committee responsible for the formulation of this standard is given in Annex E.

Indian Standard

METHODS FOR STATISTICAL QUALITY CONTROL DURING PRODUCTION

PART 2 CONTROL CHARTS FOR ATTRIBUTES

(Third Revision)

1 SCOPE

1.1 This standard (Part 2) outlines the method of control chart by attributes for controlling the quality during production. The procedure pertaining to control charts for fraction (or percent) non-conforming, number of non-conformities per item (or per 100 items) are given in general terms.

1.2 The principle of control charts by attributes has also been illustrated with a variety of examples. Certain broad guidelines for the interpretation of the data resulting from the control charts are also included.

2 REFERENCES

The following standards contain provisions, which through reference in this text constitute provisions of the standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
397	Methods for statistical quality control during production:
(Part 1) : 2003	Control charts for variables (*second revision*)
(Part 4) : 2003	Special control chart by attributes (*first revision*)
7920	Statistical vocabulary and symbols:
(Part 1) : 1994	Probability and general statistical terms (*second revision*)
(Part 2) : 1994	Statistical quality control (*second revision*)
9300 (Part 1) : 1979	Statistical models for industrial applications : Part 1 Discrete models
14977 : 2001	Control charts when inspection is by gauging

3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 7920 (Part 1) and IS 7920 (Part 2) shall apply.

4 BASIS FOR CONTROL CHARTS BY ATTRIBUTES

4.1 Some of the basic concepts underlying control charts technique have been given in detail in **4** of IS 397 (Part 1). In the case of control charts for variables, the underlying distribution of the characteristic of study was assumed to be the normal type when the process was under a state of statistical control. This fact was made use of in the development of the control charts so that a point falling outside the control limit gave a clue to the possibility of the existence of some assignable cause of variation in the process, which could be suitably rectified.

4.2 In the case of control charts for non-conforming items, the underlying distribution for the number of non-conforming items in the population is binomial distribution (*see* Annex A). If the process is being influenced by chance causes alone, the fraction non-conforming as computed from successive samples tend to approach a fixed value (p) provided the number of items inspected is very large. This value, to which the fraction non-conforming of samples approach is called a standard fraction non-conforming (or process average fraction non-conforming), and is the probability of non-conforming items from the process. Although, the population fraction non-conforming remained unchanged, the fraction non-conforming in the sample may vary quite considerably due to chance causes only. The relative frequencies of various sample fraction non-conforming items may be expected to follow the binomial law. Thus, if the process is turning out one percent non-conforming items all the time then it is mathematically possible to work out the relative frequencies of the different number of non-conforming items in successive samples of any given size. For example, if the sample size chosen is 50, then 60 percent of the samples will be free of non-conforming, 31 percent will have one non-conforming item, 8 percent will have two non-conforming items and 1 percent will have three non-conforming items.

4.2.1 For setting control limit for fraction non-conforming, the process fraction is first estimated and the standard deviation (σ) of the binomial distribution can be used to establish the 3 σ limits on the control charts for fraction non-conforming. The same general reasoning underlying the control limits on the average and range charts explained in IS 397 (Part 1) is also applied to the fraction non-conforming chart. That is to say, the control limits should be placed far enough from the expected average value so that a point outside the limits indicates either that the population has changed or that the occurrence of such point falling outside the limits is very unlikely so that it is safe to act on the assumption that the fraction non-conforming in the population has changed.

NOTE — It may be of interest to observe that as the sample size becomes larger and the process fraction non-conforming approaches the value 0.5; the binomial distribution can very well be approximated by suitable normal distribution.

4.3 In the case of control charts for non-conformities, the underlying distribution of number of non-conformities per item is of the Poisson type (*see* Annex A), wherein the opportunities for non-conformities are numerous even though the chance of non-conformity occurring at any one spot is very small. This situation holds good in a number of manufactured items, such as, the surface defects observed on a galvanized sheet, the number of seeds occurring on glass bottles and number of missing ends in a fabric and so on. In most cases each subgroup for the non-conformities chart consists of a single item and c would be the number of non-conformities observed in one item. However, it is not necessary that the subgroup for the c chart be a single item. The subgroup size may be constant or may vary. The control chart principles, when the subgroup size is constant or varying, are prescribed in this standard separately.

NOTE — It may be of interest to observe that as the size of the sample (n) increases and the fraction non-conforming (p) becomes smaller so that np is finite, then Binomial distribution can very well be approximated by suitable Poisson distribution.

5 PRELIMINARIES TO THE INSTALLATION OF CONTROL CHARTS

5.1 Choice of Quality Characteristic

In the case of attribute inspection it is possible to classify an item as non-conforming on the basis of a single stipulation or a series of stipulations. For example, a casting may be classified as a non-conforming because of the existence of one or more of different types of non-conformities like blow holes, cracks, cuts, scabs, sponginess, swells, run outs, misruns and bad surface. It is a common practice that single fraction non-conforming chart is utilized at an inspection station where many different quality characteristics are to be checked, unless there are compelling reasons for controlling the different types of non-conforming items through separate control charts. For example, while checking dimensions by 'go', 'no go' gauge, rejection by the gauge may mean re-work or spoilage depending on the particular dimension. If control is to be exercized separately for re-work and spoilage, then there is an explicit need to run a set of two fraction non-conforming charts.

5.1.1 In case of control chart for number of non-conformities, all the non-conformities on an item are counted and plotted on the control chart. This chart has a disadvantage that it gives equal importance to each class of non-conformities. But the different non-conformities are unequal in their influence on costs. Some may be corrected by simple inexpensive re-work operation, other may require costly re-work, and still others may involve the scrapping of the items inspected. A practical solution to this problem is to classify the various non-conformities into some broad categories, like critical, major and minor non-conformities and run separate control charts for each class of non-conformities. However, if the number of classes of non-conformities increase, it may be difficult to have so many control charts simultaneously. A simpler solution is to give the different demerit rating (weights) to each class of non-conformities and calculate the demerit score for each item. This demerit score may be plotted on the demerit control chart. For further details on demerit control chart, reference may be made to IS 397 (Part 4).

5.2 Inspection Aspects

Unlike the case of control charts for variables where the measurement makes the inspection more objective, in the case of attributes certain amount of subjectivity may be introduced into the inspection, especially in respect of visual characteristics. So it is very important that in the case of visual inspection of non-conformities, they have to be clearly defined and in many cases samples or specimens have to be maintained as standards. If these precautions are not taken there are chances that different quality evaluations may result where two or more inspectors evaluate the same quality or same inspector may give different evaluations over a period of time, even though the quality level has remained unchanged.

5.3 Choice of Rational Subgroups

5.3.1 As in the case of control charts for variables, in the control chart for attributes also the most natural basis for selecting rational subgroups is the order in which production takes place. Initially it may be worthwhile to chart separately the inspection results of different inspectors, production of different machines doing the same job or different shifts, etc, until the evidence shows that they can be combined. In visual inspection where judgment plays an important part there is a great chance for differences among inspectors. Even with 'go' and 'no go' gauges inspectors may differ considerably. If each subgroup is taken in a way to reflect the work of only one inspector, the fraction non-conforming chart may sometimes be used as a useful check on inspection standards only.

5.3.2 When production is not on a continuous basis, a satisfactory alternative basis of subgrouping may be to consider each production order as one subgroup. However, if the production order is too large, more than one subgroup may have to be selected.

5.4 Size of Sample

5.4.1 In order to make effective use of control charts for fraction non-conforming as an aid in process control, there must be some non-conforming items in the sample observed. It is evident that, better the quality the larger must be the sample in order to find some non-conforming items in the sample. For example, if a process is turning out only 1 percent non-conforming product, the sample size must be at least 100 before there will be an average of one non-conforming item per sample. On the other hand if 10 percent of the product is non-conforming, a sample of size 10 will give an average of one non-conforming item per sample. It is thus evident that with very good quality level the fraction non-conforming chart is useful in detecting lack of control only if the samples are large; and with poor quality, the fraction non-conforming chart may be useful even with relatively smaller sample sizes.

5.4.2 When the sample size is small, a technique for making the fraction non-conforming chart more sensitive is by resorting to control charts when inspection is by gauging (*see* IS 14977). By compressing the gauges, the percent non-conforming items are artificially increased enabling the small samples to detect the shifts in the process. This is comparable to the technique of accelerated testing resorted to in the case of some measurable characteristics. However, the theory of control charts when inspection is by gauging is outside the scope of this standard.

5.5 Choice of Types of Control Charts

5.5.1 In the case of control charts for variables it is the common practice to maintain a pair of control charts, one for the control of average level and another for the control of dispersion. This was necessary because the underlying distribution was of the normal type, which depend on two parameters. However, in the case of control charts for attributes a single chart will suffice since underlying distribution (whether of the Binomial type in the case of control charts for fraction non-conforming or Poisson type in the case of control charts for non-conformities) has only one parameter.

5.5.2 Whenever the subgroup size is variable, the control chart for fraction non-conforming (or percentage non-conforming) is preferred because if the actual number of non-conforming items were plotted, the central line of the chart as well as the limits would need to be changed with every change in subgroup size. However, if subgroup size is constant, the chart for actual number of non-conforming items may be used. One reason for preferring the number of non-conforming items chart in such case is that it saves calculation for each subgroup, namely, the division of number of non-conforming items by subgroup size to get the fraction non-conforming. It has also the added advantage that the operators more easily understand it.

6 SETTING UP OF CONTROL CHARTS

6.1 Preliminary Data Collection

After having decided upon the choice of quality characteristics (*see* **5.1**) as also the type of attribute chart to be installed (fraction non-conforming chart or chart for number of non-conformities) some initial inspection data has to be collected and analyzed for the purpose of determining the preliminary control chart values concerning the central line and the control limits. The preliminary data may be collected sample by sample (in subgroups of size and character decided upon in **5.4** and **5.5**) till at least 25 samples are obtained from the run of production process. Care is to be exercized during the course of this initial data collection that the process is not unduly influenced intermittently by extraneous factors like changes in the feed of raw material, operators, machine settings and allied process parameters like temperature and relative humidity.

6.2 Analysis of Preliminary Data

6.2.1 Analysis of preliminary data is undertaken by homogenizing the fraction non-conforming or number of non-conformities observed in the various subgroups.

6.2.2 *Homogenization for Number of Non-conforming Items for Subgroups of Equal Size*

In case the sample size for each subgroup is same (n) and number of non-conforming items chart is being used, then for homogenization, number of non-conforming items in each subgroup is compared with the upper control limit. The upper control limit in this case works out as:

$$n\overline{p} + 3\left[n\overline{p}\left(1-\overline{p}\right)\right]^{1/2}$$

where $\overline{p}$ is the average fraction non-conforming for all the subgroups.

6.2.3 *Homogenization for Fraction Non-conforming Items of Subgroups of Unequal Size*

6.2.3.1 For each of the subgroups in the preliminary data, the number of items inspected as well as number of non-conforming items found in them would have been recorded. The fraction non-conforming for each subgroup is obtained by dividing the number of non-conforming items by the corresponding number of items inspected. The overall average fraction non-conforming $\bar{p}$ is then computed by dividing the total number of non-conforming items found in all the subgroups by the total number of items inspected. Taking this average value of fraction non-conforming as the standard fraction non-conforming for the process, the upper control limit for the fraction non-conforming of any subgroup is calculated as $\bar{p} + 3\ [\bar{p}\ (1 - \bar{p})/n]^{1/2}$, where n is the size of the subgroup.

6.2.3.2 If the fraction non-conforming for each of the subgroups is less than or equal to the corresponding upper control limit, the initial data collected shall be deemed to be homogeneous for the purpose of starting the control chart. If one or more fraction non-conforming exceeds the corresponding upper control limit, then the relevant subgroup shall be discarded and a new average fraction non-conforming shall be computed for calculating the revised upper control limit. This process shall be continued till all the fraction non-conforming values are found to be within their respective upper control limits.

NOTE — When the subgroup size is different, the overall average fraction non-conforming, $\bar{p}$, for all the subgroups shall be obtained by the method given in 6.2.3.1. Another method for obtaining the overall average value by taking the average of individual fraction non-conforming values (p) is not correct and will give a different value.

6.2.4 *Homogenization for Number of Non-conformities for Subgroups of Equal Size*

6.2.4.1 When each subgroup consists of one item, the homogenization process for control chart for non-conformities, is similar to the one indicated in 6.2.3. From the initial data the average number of non-conformities $\bar{c}$ is calculated by dividing the total number of non-conformities by the total number of items inspected. The upper limit for the number of non-conformities is then calculated as

$$\bar{c} + 3\sqrt{\bar{c}}$$

and all the subgroups having non-conformities in excess of this upper limit are discarded. From the remaining, a new average number of non-conformities is calculated and the above procedure is repeated till all the number of non-conformities for each subgroup become less than or equal to the upper control limit.

6.2.4.2 Homogenization for number of non-conformities when the subgroup contains equal number of items (more than one) is done by counting the total number of non-conformities on all items inspected in each subgroup. This total number of non-conformities from each subgroup may be taken as the number of non-conformities on one item and the process of homogenization will be same as in 6.2.4.1.

6.2.5 *Homogenization for Number of Non-conformities per Item for Subgroups of Unequal Size*

If the number of items in different subgroups is not equal then the number of non-conformities per item is calculated. In the ith subgroup the number of non-conformities per item, c_i, may be calculated by dividing the total number of non-conformities in the subgroup by the number of items inspected (n_i) in that subgroup. The average number of non-conformities per item ($\bar{c}$) for all the subgroups is calculated by dividing the total number of non-conformities in all the subgroups by total number of items inspected in all the subgroups. Taking this average value of the number of non-conformities per item as the standard value of number of non-conformities per item, the upper control limit for the ith subgroup is calculated as:

$$\bar{c} + 3\ (\bar{c}/n_i)^{1/2}$$

If the number of non-conformities per item for each subgroup is less than or equal to the corresponding upper control limit, the initial data collected shall be deemed to be homogeneous for the purpose of starting the control chart. If the number of non-conformities per item for one or more subgroups exceeds the corresponding upper control limit, then the relevant subgroup shall be discarded and a new average number of non-conformities per item shall be calculated till the number of non-conformities per item for all the remaining subgroups is found to be within its upper control limit.

6.2.6 In the above process of homogenization, if large number of the samples, say 25 percent or more are rejected for being out of control, entire data may be rejected and fresh collected after checking the process and eliminating the assignable causes which were responsible for the high rate of rejection in the preliminary data.

6.3 Control Limits

6.3.1 *Fraction Non-conforming*

6.3.1.1 The central line for the fraction non-conforming chart is the ultimate average fraction non-conforming of the homogenized data '$\bar{p}$' obtained according to 6.2.2. The upper and lower control limits for the fraction non-conforming chart are obtained as follows:

$$UCL = \bar{p} + 3\left[\bar{p}(1-\bar{p})/n\right]^{1/2}$$

$$LCL = \bar{p} - 3\left[\bar{p}(1-\bar{p})/n\right]^{1/2}$$

If LCL is negative, it is taken as zero.

6.3.1.2 In case it is preferred to maintain the percentage non-conforming chart instead of the fraction non-conforming chart, then the central line is drawn at 100 $\bar{p}$ and the control limits are obtained as follows:

$$UCL = P + 3\,[P\,(100 - P)/n]^{1/2}$$

$$LCL = P - 3\,[P\,(100 - P)/n]^{1/2}$$

where $P = 100\,\bar{p}$

NOTE — For the sake of convenience, UCL and LCL corresponding to different percentage non-conforming values and subgroup sizes are tabulated in Annex B.

6.3.1.3 The exact formula for the calculation of UCL and LCL for the fraction non-conforming chart as given in **6.3.1** depends upon the actual subgroup size. However, where the variation in subgroup size is not large (for example, where the maximum and minimum subgroup sizes are not more than 10 percent away from the average), it may often be adequate for all practical purposes to establish a single set of control limits based on the average subgroup size. This would considerably simplify the operation of the fraction non-conforming chart, not necessitating the calculation of the control limits for each subgroup separately. However, if the subgroup sizes are differing much, control limits for each subgroup have to be computed separately. Alternatively, two sets of control limits may be calculated based on the minimum and the maximum sample sizes. If the fraction non-conforming for a subgroup lies within the inner set of limits (the limits obtained for maximum sample size) (*see* Region *A* in Fig. 1), the process is in control and no action need be taken. If the fraction non-conforming for a subgroup lies beyond the outer set of limits (the limits obtained for minimum sample size) (*see* Region *D* and *E* in Fig. 1) the process is out of control and therefore action must be taken. For the remaining subgroups, for which the fraction non-conforming lies between the two control limits (on the same side of central line), that is, a point falling in the (*see* Region *B* or *C* in Fig. 1), actual control limits for the subgroups shall be calculated and action should be based on these actual control limits. For example, if a point falls in the Region *C*, the upper control limit is to be determined corresponding to the sample size of the subgroup under consideration and inference should be based on the comparison of the point with this control limit.

The other method, when subgroup size is much different, is to use standardized p-chart. For further details of this chart, *see* IS 397 (Part 4).

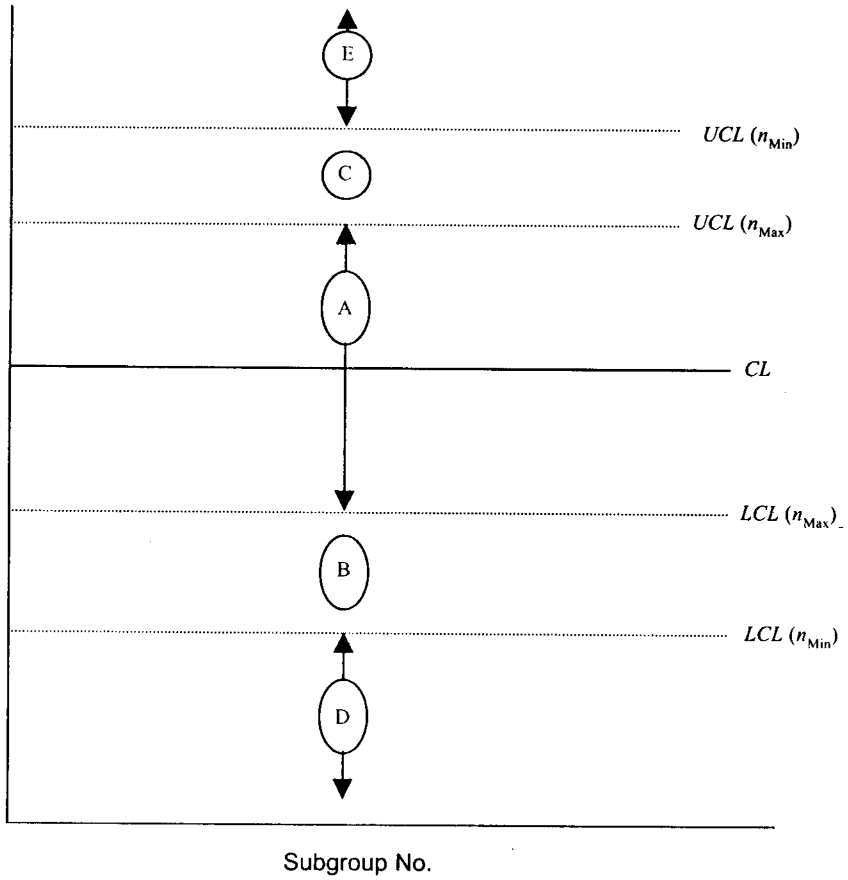

FIG. 1 CONTROL LIMITS FOR MAXIMUM AND MINIMUM SAMPLE SIZE IN p-CHART

6.3.2 *Number of Non-conforming Items*

As already indicated (*see* **5.5.2**) the number of non-conforming items chart is preferred when the subgroup size is constant. The central line for the number of non-conforming items chart is obtained as $n\bar{p}$ and upper and lower control limits are obtained as follows:

$$UCL = n\bar{p} + 3\left[n\bar{p}(1-\bar{p})\right]^{1/2}$$
$$LCL = n\bar{p} - 3\left[n\bar{p}(1-\bar{p})\right]^{1/2}$$

where 'n' is the number of items in each subgroup and $\bar{p}$ is the average fraction non-conforming from the homogenized data (*see* **6.2.2**).

If *LCL* is negative, it is taken as zero.

6.3.3 *Number of Non-conformities for Subgroups of Equal Size*

The central line for the number of non-conformities chart is drawn at the average number of non-conformities, $\bar{c}$, obtained from the homogenized data (*see* **6.2.4**). The upper and lower control limits for the non-conformities chart are obtained as follows:

$$UCL = \bar{c} + 3\sqrt{\bar{c}}$$
$$LCL = \bar{c} - 3\sqrt{\bar{c}}$$

If *LCL* is negative, it is taken as zero.

NOTE — For the sake of conveniences, *UCL* and *LCL* corresponding to different average number of non-conformities, varying from 0 to 100, are tabulated in Annex C.

6.3.4 *Number of Non-conformities per Item for Subgroups of Unequal Size*

This chart is favoured when the number of items are unequal in different subgroups. The central line for this chart is drawn at the average number of non-conformities per item $\bar{c}$, as obtained from the homogenized data (*see* **6.2.5**). The upper and lower control limits for *i*th subgroup are obtained as follows:

$$UCL = \bar{c} + 3(\bar{c}/n_i)^{1/2}$$
$$LCL = \bar{c} - 3(\bar{c}/n_i)^{1/2}$$

where n_i is the size of the *i*th subgroup.

If *LCL* is negative, it is taken as zero.

6.4 Charts Based on Known Values

The fraction non-conforming chart is not only used for finding the presence or absence of assignable causes of variation, but may also be utilized for judging whether the quality level is at some desired value. In the latter context, it is logical to use the desired value of fraction non-conforming as the standard value in the construction of the control charts. However, if this value is smaller than the homogenized value of fraction non-conforming got from the initial data (*see* **6.2.3**) then the use of the desired value for the control chart purpose may result in the large number of points falling outside the upper control limit. This may make the chart ineffective for the purpose of detection of assignable causes of variation. So unless the desired fraction non-conforming is close to the homogenized fraction non-conforming obtained from the preliminary data, it is advisable to use the latter for the purpose of control chart. However, after maintaining the chart for some time and ensuring that the process is stabilized in a state of statistical control, the standard fraction non-conforming is then re-evaluated and used subsequently.

6.5 Some Practical Guidelines for Drawing the Control Chart

As in the case of control charts for variables, control charts for attributes are also drawn on a cross-sectional or graph paper. The horizontal scale indicates the subgroup number (possibly designated by data and sample number) whereas the statistical measure chosen such as fraction non-conforming, number of non-conforming items, number of non-conformities or number of non-conformities per item is represented on the vertical scale. It is usually satisfactory to use the millimetre graph paper wherein the subgroup numbers are indicated on the horizontal scale at intervals of not less than 5 mm. The various pointed plotted on the control charts are generally connected with straight lines for assisting in the interpretation of the charts with regard to existing trends, etc.

6.5.1 A typical proforma for collection of data on control charts for attributes is given in Annex D.

7 MAINTENANCE OF CONTROL CHARTS

7.1 For some general guidance with regard to the usage of control charts during production of the detection of assignable causes, reference is invited to 7 of IS 397 (Part 1).

7.2 Some Guidelines for Interpretation

7.2.1 In the operation of the control chart for fraction non-conforming there may be erratic changes in the quality level for an occasional subgroup, eventhough quality is otherwise maintained at the standard fraction non-conforming. Such changes are shown by points outside the control limits and are evidence of assignable causes of variation.

7.2.2 In most of the control charts for fraction non-conforming which are operated for considerable length of time, there may also be definite sustained shifts of average fraction non-conforming to new level which is either better or worse than the standard adopted. Such departures from the standard fraction non-conforming are often evident merely from inspection of the control chart without any application of any formal statistical test. Extreme runs above or below the central line, as well as points outside control limits may be used to provide tests that supplement observation of the chart.

7.2.3 For the purpose of a statistical test, any consecutive set of subgroups may be combined into single subgroup. In this way the average fraction non-conforming of a set of subgroups may be tested to see whether it varies more than 3σ from the standard fraction non-conforming. Thus if p' is the standard fraction non-conforming on which the control charts are being operated and for a period of time the fraction non-conforming is obtained as $\overline{p}$ (based on a sample of size n obtained by combining some of the consecutive subgroups) then there is definite evidence of shift in the average level if the difference between p' and $\overline{p}$ is more than $3[p'(1-p')/n]^{1/2}$

7.2.4 When there is consistent evidence of decrease in the average fraction non-conforming, it should be first verified whether this is due to improper inspection. In case improper inspection is the cause of apparent improvement of quality the same will also be reflected by the control chart by many points falling below the lower control limit. On ascertaining that the decrease in the average fraction non-conforming is due to genuine quality improvement, the standard average fraction non-conforming may be revised downwards for making better quality products. On the other hand if the average fraction non-conforming shows upward trend, all the possible reasons should be investigated. The possible causes may be the adoption of more stringent specification limits, more rigorous enforcement of the existing limits by the inspectors, poorer incoming raw materials, wear and tear of the machinery, etc. After ascertaining the genuine reason for the quality deterioration all efforts shall be made to rectify the cause. An upward revision of the standard fraction non-conforming is permissible only in exceptional cases after ensuring that all assignable causes have been investigated and rectified.

7.2.5 A note of caution may not be out of place in the use of fraction non-conforming charts. It has been stated earlier (*see* **4.2**) that the fraction non-conforming chart is based on Binomial distribution which assumes a constant probability of occurrence for the non-conforming item. So if from the way in which manufacturing or inspection operations are carried out it is obvious that the successive items measured are not independent of one another then most of the points on the conventional fraction non-conforming chart may fall outside the control limits thereby making the chart unusable or even misleading.

7.2.6 Although the detection of assignable causes of variation affecting the process is one main purpose of all control charts, the control charts for fraction non-conforming is more often used to know the time at which lack of control was observed. On the other hand the control chart for variables such as mean chart and range chart described in IS 397 (Part 1) are very effective for the diagnosis of the causes as to why product has failed to meet the specification requirements. Thus fraction non-conforming chart may point to the place for effective use of the control charts for variables.

8 ILLUSTRATIVE EXAMPLES

8.1 Examples for Installing Control Chart for Fraction Non-conforming

8.1.1 In a bicycle manufacturing company, which also produces the various components which go into the assemblies, it was decided to instal a fraction non-conforming chart for nipples finishing machine. The various non-conformities that could be observed in the nipple were recognized as follows:

a) Counter drilling non-conformities,
b) Loose core diameter,
c) Milling non-conformity,
d) Head slotting non-conformity, and
e) Threading non-conformity.

A nipple which had one or more of the above non-conformities was classified as a non-conforming.

8.1.2 It was decided that the initial data for nipples produced during the month of August was to be collected and analyzed for the installation of fraction non-conforming chart. From each day's production a random sample was to be collected at the end of the day and examined for the number of non-conforming items. The data so collected for the month of August is given in Table 1.

8.1.3 From the initial data for each of subgroups, the fraction non-conforming was computed by dividing the total number of non-conforming items by the corresponding number of nipples inspected. The average fraction non-conforming was then calculated as follows:

$$\overline{p} = 233/3\ 893 = 0.060$$

8.1.4 For homogenizing the various fraction non-conforming values, upper control limits for different subgroups were calculated as $\bar{p} + 3 [\bar{p} (1 - \bar{p})/n]^{1/2}$, where n was size of the subgroup. The *UCL*'s corresponding to different subgroups are given in col 6 of Table 1. It was observed that the fraction non-conforming corresponding to subgroup numbers 4 and 13 were falling outside the corresponding upper control limits and hence these two subgroups were discarded from the initial data. From the remaining 24 subgroups, a revised average fraction non-conforming was computed as follows:

$$\bar{p} = (233 - 38)/(3\,893 - 297) = 195/3\,596 = 0.054$$

UCL's for the various subgroups were then re-calculated with the help of the revised average fraction non-conforming (*see* col 7 of Table 1) and it was then observed that all the fraction non-conforming values were within the corresponding *UCL*'s. Hence that revised value of average fraction non-conforming (equal to 0.054) was taken as the standard fraction non-conforming for the purpose of installation of control chart. The *LCL* for each of the subgroups, when calculated, came out as negative, and therefore was taken as zero. The control chart for the data is given in Fig. 2.

8.1.5 From the computation given in Table 1, it was evident that with the varying subgroup size, the control limits would have to be calculated for each subgroup separately. Moreover, the subgroup sizes were not widely varying from the average subgroup size of 150. In order to simplify the computational work, it was decided to have subgroups of constant size, namely, of 150 nipples for each subgroup. It was also agreed that a control chart for the number of non-conforming items would be still easier to maintain since it eliminated the calculation of even the fraction non-conforming for each subgroup. Accordingly, taking

Table 1 Control Chart Data Sheet (Initial Data)

(*Clauses* 8.1.2, 8.1.4 *and* 8.1.5)

Product: Nipple	Sample Size: Varying	Production Order No.:	
Characteristic: *See* **8.1.1**	Frequency: Once a day		
Inspector:	Period: August	Workshop:	
	Operator:	Machine No. :	

Subgroup No. (1)	Date (2)	No. Inspected (3)	No. of Non-conforming Items (4)	Fraction Non-conformity (5)	*UCL* (6)	*UCL* Revised (7)	Remarks (8)
1	2	145	8	0.055	0.119	0.110	
2	3	160	6	0.038	0.116	0.108	
3	4	165	15	0.091	0.115	0.107	
4	5	136	18	0.132[1)]	0.121	0.112	
5	6	153	10	0.065	0.118	0.112	
6	7	150	9	0.060	0.118	0.109	
7	9	148	5	0.034	0.119	0.109	
8	10	135	0	0.000	0.121	0.110	
9	11	165	12	0.073	0.115	0.107	
10	12	143	10	0.070	0.120	0.111	
11	13	138	8	0.058	0.121	0.112	
12	14	144	14	0.097	0.119	0.111	
13	16	161	20	0.124[1)]	0.116	0.107	
14	17	158	11	0.070	0.117	0.108	
15	18	140	11	0.079	0.120	0.111	
16	19	140	8	0.057	0.120	0.111	
17	20	155	6	0.039	0.117	0.108	
18	21	160	4	0.025	0.116	0.108	
19	23	144	7	0.049	0.119	0.111	
20	24	139	10	0.072	0.120	0.112	
21	25	151	11	0.073	0.118	0.109	
22	26	163	9	0.055	0.116	0.107	
23	27	148	5	0.034	0.119	0.110	
24	28	150	2	0.013	0.118	0.109	
25	30	153	7	0.046	0.118	0.109	
26	31	149	7	0.047	0.118	0.110	
	Total	3 893	233				

1) Indicates data dropped for homogenization.

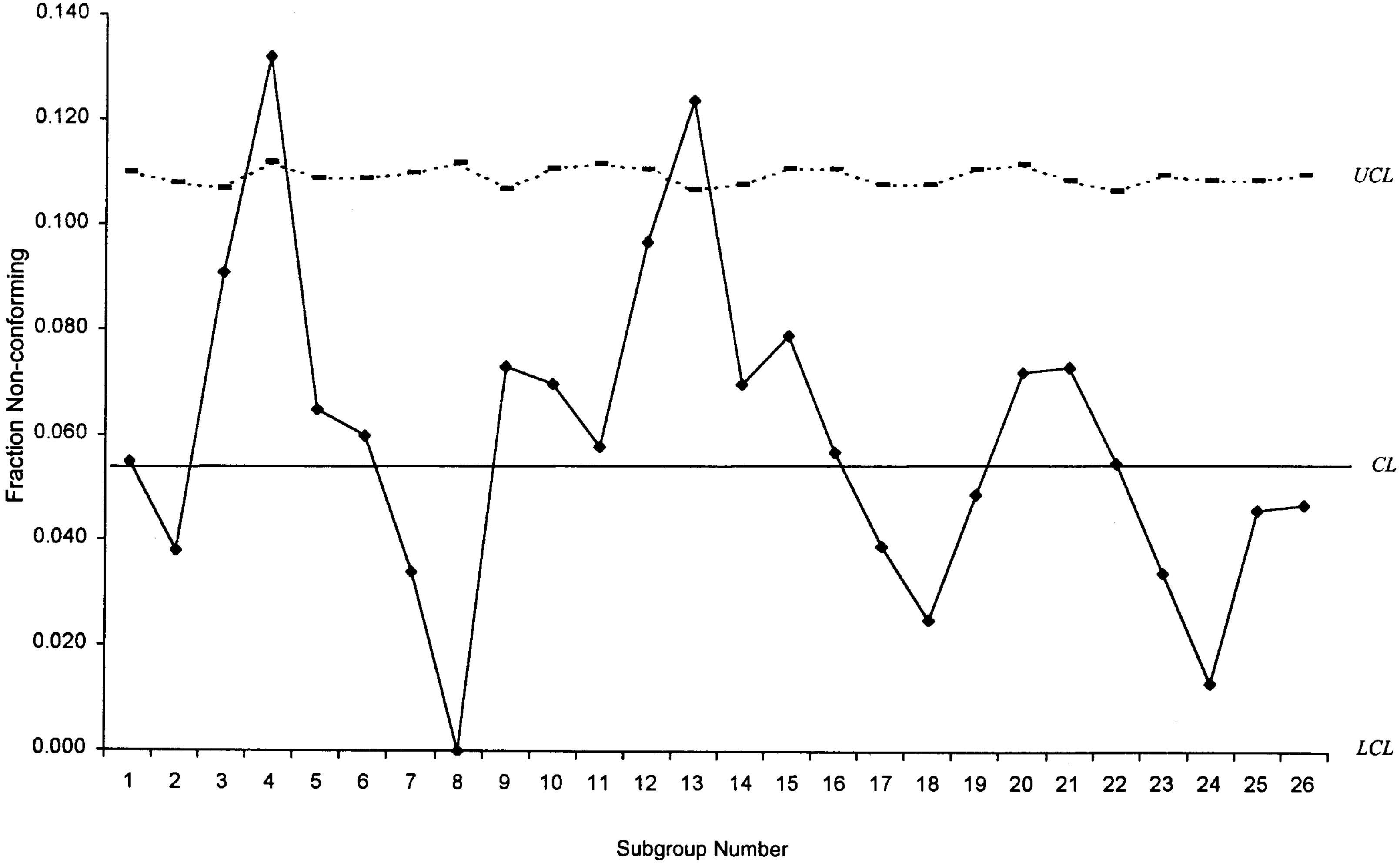

FIG. 2 CONTROL CHART FOR FRACTION NON-CONFORMING

the standard fraction non-conforming as 0.054, the central line and the control limits for the number of non-conforming items chart with subgroup size equal to 150 were computed as follows:

Central line $(n\bar{p}) = 150 \times 0.054 = 8.1$

$UCL = n\bar{p} + 3\,[n\bar{p}\,(1-\bar{p})]^{1/2} = 8.1 + 8.3 = 16.4$

$LCL = 8.1 - 8.3$, which was taken as 0, since the value became negative.

With these values the chart for number of non-conforming items was maintained for the month of September. The operational data for the number of non-conforming items chart is given in Table 2 and the control chart is plotted in Fig. 3.

Table 2 Control Chart Data Sheet (Subsequent Data)

(*Clause* 8.1.5)

Product: Nipple	Sample Size: 150	Production Order No.:	
Characteristic: *See* **8.1.1**	Frequency: Once a day		
No. inspected: 150	Period: September	Workshop:	
Inspector:	Operator:	Machine No.:	

Subgroup No. (1)	Date (2)	Number of Non-conforming Items (3)	Remarks (4)
1	1	7	
2	2	6	
3	3	11	
4	4	0	
5	6	7	
6	7	12	
7	8	11	
8	9	5	
9	10	3	
10	11	14	
11	13	12	
12	14	9	
13	16	4	
14	17	3	
15	18	11	
16	20	8	
17	21	7	
18	22	8	
19	23	7	
20	24	8	
21	25	17	Change of raw material source
22	27	4	
23	28	8	
24	29	12	
25	30	13	
	Total	207	

8.2 Example for Installing Control Chart for Number of Non-conformities

8.2.1 In a plant processing bicycle frames it was decided to install a control chart for non-conformities for controlling the surface finish of the bicycle frames. From the past experience it was known that a non-conformity of one per frame was reasonable and so it was decided to adopt this value as a standard for the number of non-conformities chart. Accordingly, the *UCL* and *LCL* for the number of non-conformities chart were calculated as follows:

$UCL = 1 + 3\sqrt{1} = 4$

$LCL = 1 - 3\sqrt{1} = -2$ which was taken as 0, since it was negative.

With these values as the control limits, a control chart was installed. A total number of 25 frames were selected from each day's production and the number of scratches and rusty patches found on each of the frames were plotted on the control chart. The data for the first four days is given in Table 3 and has also been plotted in Fig. 4.

8.2.2 From the study of Fig. 4 it is evident that during the first three days, the chart was working more or less satisfactorily. However, on the fourth day there seemed to be a shift in the average number of non-conformities per frame. The shift was evident even from a mere observation of the various points plotted on the control chart. Besides one point going out of control, which clearly indicated that the process was no longer working at the presumed level of one non-conformity per frame, it could also be seen that only two points were below the central line whereas 12 points were above the central line even after excluding the single point which was out of control. The average number of non-conformities found during the fourth day was computed as 1.76 which was clearly on the higher side as compared to the assumed average number of one non-conformity per frame.

8.3 Example for Installing Chart for Number of Non-conformities per Item for Subgroups of Unequal Size

8.3.1 In cast iron foundry, number of engine blocks produced in batch vary. It was decided that the entire batch should be taken as one subgroup. All the items from each batch were inspected and the number of non-conformities obtained are given in Table 4.

8.3.2 Since the number of items in each batch was varying, a control chart for number of non-conformities per item was installed.

8.3.3 From the initial data, for each of the subgroups, the number of non-conformities per item was calculated by dividing the number of non-conformities in the subgroup by the number of items inspected in that subgroup. The average number of non-conformities per item was calculated as follows:

$$\bar{c} = 153/476 = 0.32$$

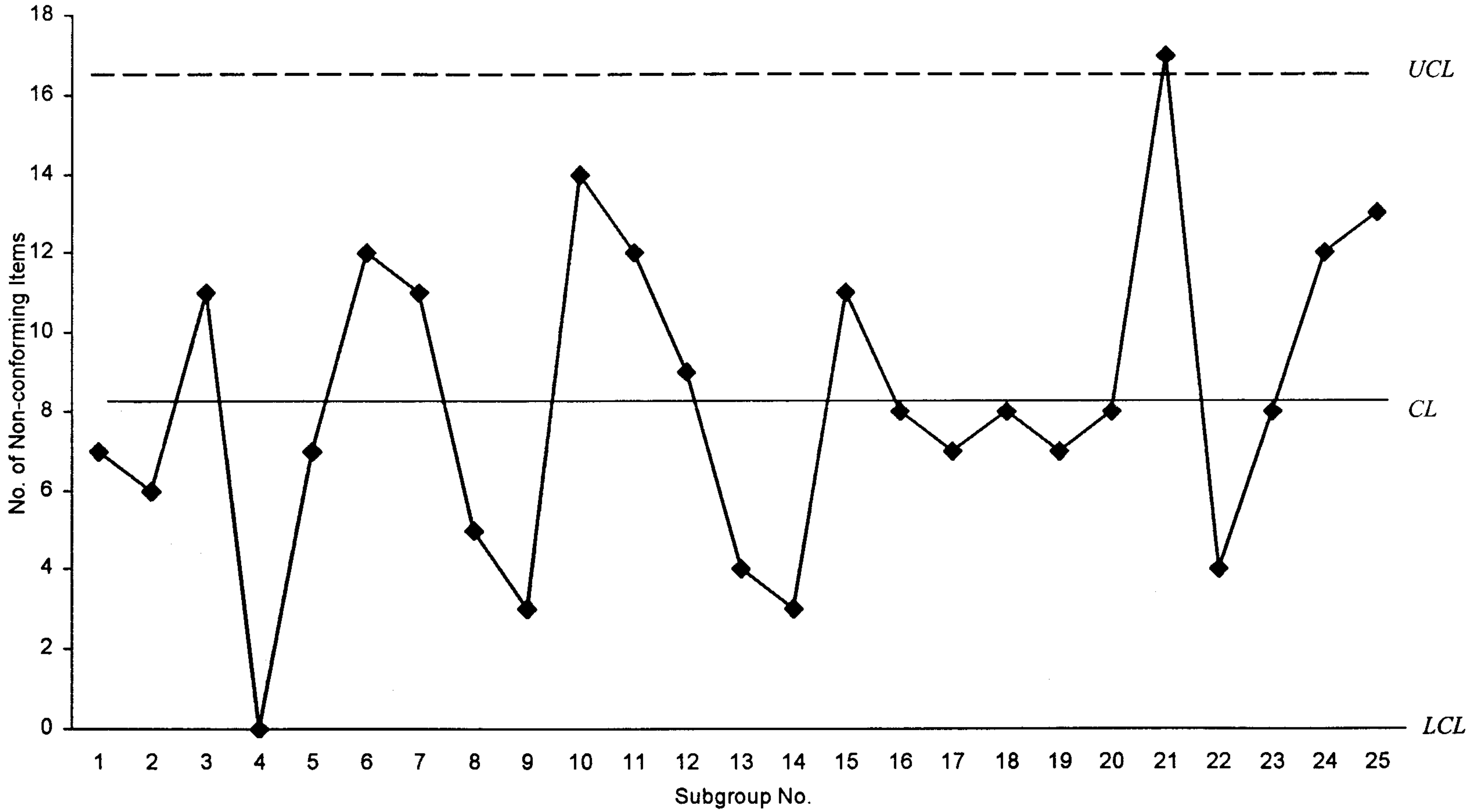

FIG. 3 CONTROL CHART FOR NUMBER OF NON-CONFORMING ITEMS

Table 3 Control Chart Data Sheet

(*Clause* 8.2.1)

Product:	Bicycle frame	Sample size:	25 Frames	Production
Characteristic:	Surface finish	Frequency:	Once a day	Order No.:
Inspector:		Period:	First week of November	Workshop:
		Operator:		Machine No.:

Sl No.	Number of Defects Founds on				Remarks
	1st Day	2nd Day	3rd Day	4th Day	
(1)	(2)	(3)	(4)	(5)	(6)
1	1	2	0	2	
2	1	2	2	0	
3	0	0	2	1	
4	2	0	0	2	
5	0	2	1	2	
6	2	1	1	1	
7	0	0	1	1	
8	3	1	1	5	
9	3	0	0	1	
10	0	2	4	1	
11	1	0	0	1	
12	0	3	1	0	
13	1	1	0	2	
14	1	0	1	3	
15	0	0	3	1	
16	0	2	1	1	
17	2	2	1	3	
18	0	1	0	1	
19	4	1	3	4	
20	0	0	2	2	
21	0	0	1	2	
22	3	1	1	2	
23	0	1	2	3	
24	0	1	0	1	
25	0	0	2	2	
Total	24	23	30	44	

A daily review on the basis of control chart on number of non-conformities day basis shall be worth the extra effort. In this case, daily control limits will be :

$$CL = 25$$
$$UCL = 25 + 3\sqrt{25} = 25 + 15 = 40$$
$$LCL = 25 - 15 = 10$$

8.3.4 For homogenizing the number of non-conformities per item, upper control limit for each subgroup was calculated as $c + 3\sqrt{c/n_i}$ where n_i is the size of *i*th subgroup. The *UCL*'s corresponding to different subgroups are indicated in col 6 of Table 4. By comparing the number of non-conformities per item of each subgroup with its *UCL* it was observed that number of non-conformities per item corresponding to subgroup number 5, 12 and 14 were falling outside the corresponding *UCL* and hence these three subgroups were discarded from the initial data. From the remaining 21 subgroups a revised average number of non-conformities per item was computed as follows:

$$\bar{c} = (153 - 51)/(476 - 71) = 102/405 = 0.25$$

UCL's for various subgroups were recalculated with the help of the revised average number of non-conformities per item, and are given in col 7 of Table 4. It was observed that the number of non-conformities per item for each subgroup was within respective *UCL*. Hence, that revised value of the average number of non-conformities per item (equal to 0.25) was taken as the standard average number of non-conformities per item for the purpose of installation of control chart. The *LCL* for each subgroup was coming out as negative, and hence taken as zero.

8.3.5 The control chart for number of non-conformities per item is given in Fig. 5.

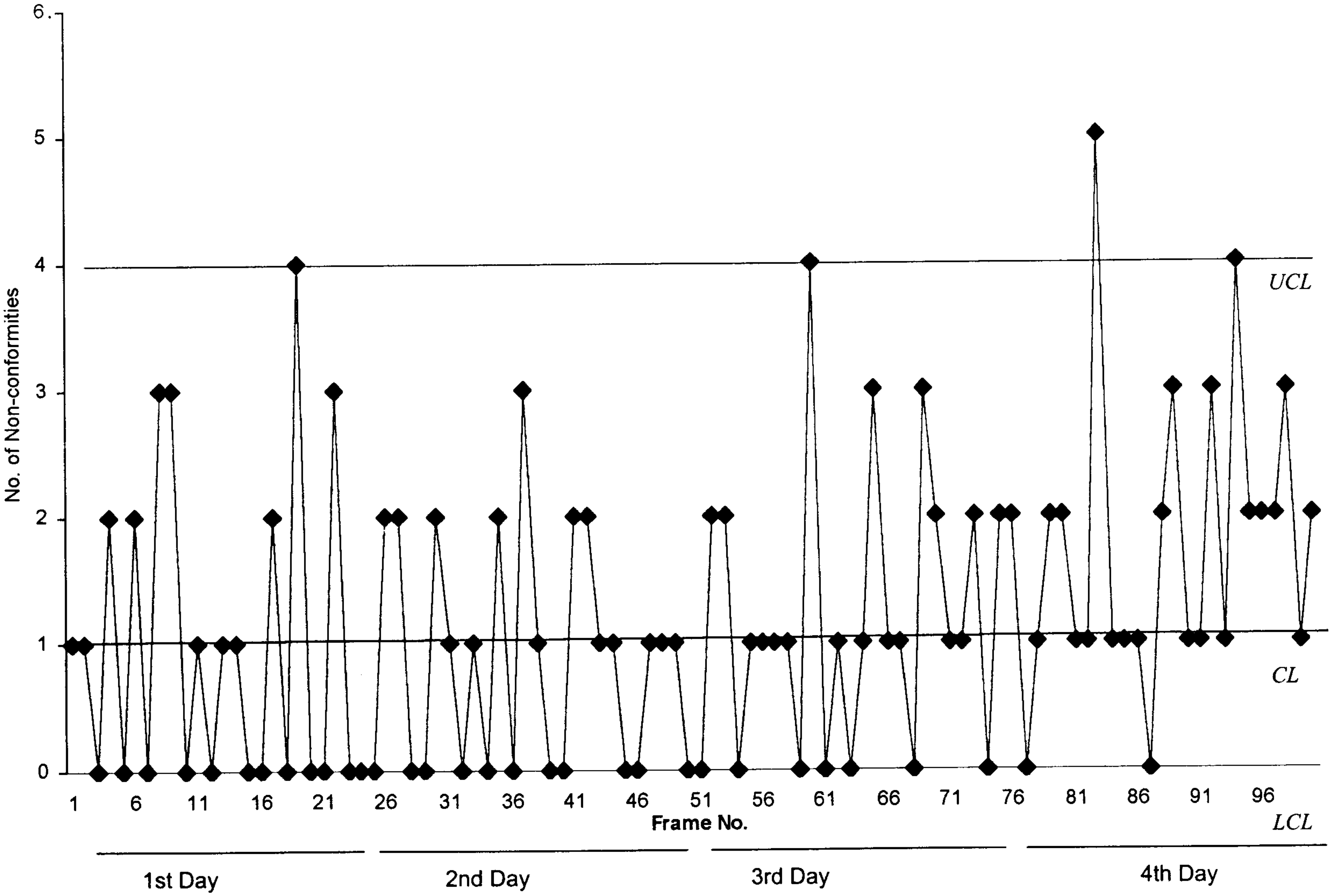

FIG. 4 CONTROL CHART FOR NON-CONFORMITIES

Table 4 Control Chart Data Sheet

(*Clauses* 8.3.1 *and* 8.3.4)

Product:	Engine blocks	Sample Size:	Varying	Production
Characteristic:	Casting defect	Frequency:	Each batch	Order No. :
Period:	March	Operator:		Workshop:
		Inspector:		Machine No.:

Batch No. (1)	Day (2)	No. of Items (3)	No. of Non-conformities (4)	Non-conformities per Item (5)	*UCL* (6)	Revised *UCL* (7)	Remarks (8)
1	2	25	6	0.24	0.662	0.553	
2	2	20	5	0.25	0.703	0.589	
3	2	15	5	0.33	0.762	0.641	
4	3	20	4	0.20	0.703	0.589	
5	3	28	19	0.68	0.644	0.536	
6	3	22	6	0.27	0.685	0.573	
7	4	15	3	0.20	0.762	0.641	
8	4	30	5	0.17	0.633	0.527	
9	5	25	7	0.28	0.662	0.553	
10	5	18	8	0.44	0.723	0.607	
11	5	10	3	0.30	0.860	0.728	
12	6	25	18	0.72	0.662	0.553	
13	6	21	8	0.38	0.693	0.580	
14	6	18	14	0.78	0.723	0.607	
15	7	24	7	0.29	0.669	0.559	
16	8	16	4	0.25	0.748	0.628	
17	8	22	6	0.27	0.685	0.573	
18	8	15	4	0.27	0.762	0.641	
19	9	22	5	0.23	0.685	0.573	
20	9	20	3	0.15	0.703	0.589	
21	9	15	4	0.27	0.762	0.641	
22	10	20	4	0.20	0.703	0.589	
23	10	15	2	0.13	0.762	0.641	
24	10	15	3	0.20	0.762	0.641	
	Total	476	153				

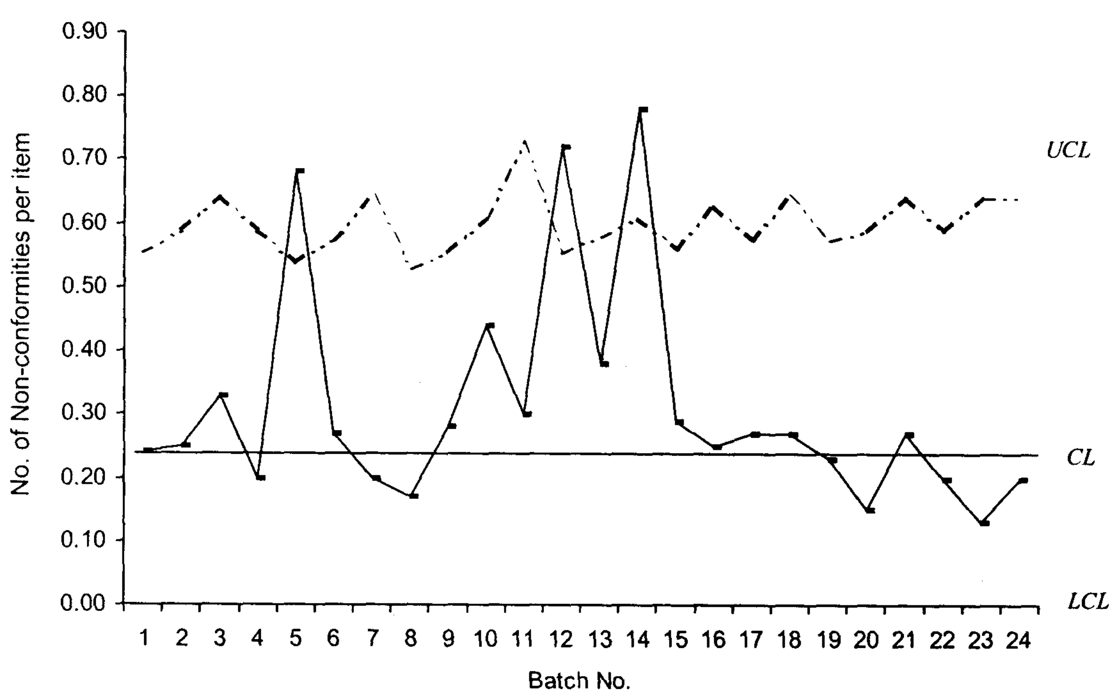

FIG. 5 CONTROL CHART FOR NON-CONFORMITIES PER ITEM

ANNEX A

(*Clauses* 4.2 *and* 4.3)

BINOMIAL AND POISSON DISTRIBUTIONS

A-1 BINOMIAL DISTRIBUTION

A-1.1 When the probability of occurrence of an event is a constant p, then in a series of n independent trials, the probability of the occurrence of the event exactly r times is given by $^{n}c_{r}\, p^{r}(1-p)^{n-r}$. The probability distribution of r which can take any one of the integral values 0, 1, 2, ..., n is that of the binomial type.

A-1.2 If a lot contains a large number of items with a proportion of non-conforming items p then a simple random sample of n items from the lot may contain 0, 1, 2,......, n non-conforming items and the probabilities associated with these events are given with a good approximation by the Binomial distribution having parameter p on the condition that sample size is small with regard to the lot size.

A-1.3 For further details, *see* IS 9300 (Part 1).

A-2 POISSON DISTRIBUTION

A-2.1 When the probability of occurrence of an event (p) is extremely small, and size of the sample n is very large such that $np = \lambda$ (constant), then the probability of the occurrence of the event exactly r times is given by $e^{-\lambda}\ \lambda^{r}/r!$, where e is the basis of natural logarithms. The probability distribution of r which can take anyone of the integral values, 0, 1, 2,..... is that of the Poisson type.

A-2.2 If the average number of non-conformities observed per item is given by λ, then the probability of getting an item with r non-conformities is given by $e^{-\lambda}\ \lambda^{r}/r!$, where r can take values 0, 1, 2, ...

A-2.3 For further details, *see* IS 9300 (Part 1).

ANNEX B

(*Clause* 6.3.1.2)

UCL AND *LCL* FOR CONTROL CHART FOR PERCENTAGE NON-CONFORMITY

Percentage	*Subgroup Size*																		
	20	30	40	50	60	70	80	90	100	125	150	175	200	250	300	350	400	450	500
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
0.5	5.23	4.36	3.85	3.49	3.23	3.03	8.45	2.73	2.62	2.39	2.23	2.10	2.00	1.84	1.72	1.63	1.56	1.50	1.45
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.0	7.67	6.45	5.72	5.22	4.85	4.57	11.27	4.15	3.98	3.67	3.44	3.26	3.11	2.89	2.72	2.60	2.49	2.41	2.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.5	9.65	8.16	7.27	6.66	6.21	5.86	13.47	5.34	5.15	4.76	4.48	4.26	4.08	3.81	3.61	3.45	3.32	3.22	3.13
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.0	11.39	9.67	8.64	7.94	7.42	7.02	15.37	6.43	6.20	5.76	5.43	5.17	4.97	4.66	4.42	4.24	4.10	3.99	3.88
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.12
2.5	12.97	11.05	9.91	9.12	8.55	8.10	17.08	7.44	7.18	6.69	6.32	6.04	5.81	5.46	5.20	5.00	4.84	4.71	4.59
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.29	0.41
3.0	14.44	12.34	11.09	10.24	9.61	9.12	18.66	8.39	8.12	7.58	7.18	6.87	6.62	6.24	5.95	5.74	5.56	5.41	5.29
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.26	0.44	0.59	0.71
3.5	15.83	13.57	12.22	11.30	10.62	10.09	20.15	9.31	9.01	8.43	8.00	7.67	7.40	6.99	6.68	6.45	6.26	6.10	6.97
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.55	0.74	0.90	1.03
4.0	17.15	14.73	13.30	12.31	11.59	11.03	21.55	10.20	9.88	9.26	8.80	8.44	8.16	7.72	7.39	7.14	6.94	6.77	6.63
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.61	0.86	1.06	1.23	1.37
4.5	18.41	15.85	14.33	13.30	12.53	11.93	22.89	11.06	10.72	10.06	9.58	9.20	8.90	8.43	8.09	7.82	7.61	7.43	7.28
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.57	0.91	1.18	1.39	1.57	1.72
5.0	19.62	16.94	15.34	14.25	13.44	12.81	24.18	11.89	11.54	10.85	10.34	9.94	9.62	9.14	8.77	8.49	8.27	8.08	7.92
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.38	0.86	1.23	1.51	1.73	1.92	2.08
6.0	21.93	19.09	17.26	16.08	15.20	14.52	26.63	13.51	13.12	12.37	11.82	11.39	11.04	10.51	10.11	9.81	9.56	9.36	9.19
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.61	0.96	1.4 9	1.89	2.19	2.44	2.64	2.81
7.0	24.12	20.97	19.10	17.82	16.88	16.15	28.94	15.07	14.65	13.85	13.25	12.79	12.41	11.84	11.42	11.09	10.83	10.61	10.42
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.75	1.21	1.59	2.16	2.58	2.91	3.17	3.39	3.58
8.0	26.20	22.86	20.87	19.51	18.51	17.73	31.14	16.58	16.14	15.28	14.65	14.15	13.75	13.15	12.70	12.35	12.07	11.84	11.64
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.72	1.35	1.85	2.25	2.85	3.30	3.65	3.93	4.16	4.36
9.0	28.20	24.67	22.57	21.14	20.08	19.26	33.25	18.05	17.59	16.68	16.01	15.49	15.07	14.43	13.96	13.59	13.29	13.05	12.84
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	1.32	1.99	2.51	2.93	3.57	4.04	4.41	4.71	4.95	5.16
10.0	30.12	26.43	24.23	22.73	21.62	20.76	35.29	19.49	19.00	18.05	17.35	16.80	16.36	15.69	15.20	14.81	14.50	14.24	14.02
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51	1.00	1.95	2.65	3.20	3.64	4.31	4.80	5.19	5.50	5.76	6.98

Percentage	*Subgroup Size*																		
	20	30	40	50	60	70	80	90	100	125	150	175	200	250	300	350	400	450	500
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
11.0	31.99	28.14	25.84	24.27	23.12	22.22	37.26	20.89	20.39	19.40	18.66	18.10	17.64	16.94	16.42	16.02	15.69	15.42	15.20
	0.00	0.00	0.00	0.00	0.00	0.00	0.51	1.11	1.61	2.60	3.34	3.90	4.36	5.06	5.58	5.98	6.31	6.58	6.80
12.0	33.80	29.80	27.41	25.79	24.59	23.65	39.18	22.28	21.75	20.72	19.96	19.37	18.89	18.17	17.63	17.21	16.87	16.60	16.36
	0.00	0.00	0.00	0.00	0.00	0.35	1.10	1.72	2.25	3.28	4.04	4.63	5.11	5.83	6.37	6.79	7.13	7.40	7.64
13.0	35.56	31.42	28.95	27.27	26.02	25.06	41.04	23.63	23.09	22.02	21.24	20.63	20.13	19.38	18.82	18.39	18.04	17.76	17.51
	0.00	0.00	0.00	0.00	0.00	0.94	1.72	2.37	2.91	3.98	4.76	5.37	5.87	6.62	7.18	7.61	7.96	8.24	6.49
14.0	37.28	33.01	30.46	28.72	27.44	26.44	42.87	24.97	24.41	23.31	22.50	21.87	21.36	20.58	20.01	19.56	19.20	18.91	18.66
	0.00	0.00	0.00	0.00	0.56	1.56	2.36	3.03	3.59	4.69	5.50	6.13	6.64	7.42	7.99	8.44	8.80	9.09	9.34
15.0	38.95	34.56	31.94	30.15	28.83	27.80	44.65	26.29	25.71	24.58	23.75	23.10	22.57	21.77	21.18	20.73	20.36	20.05	19.79
	0.00	0.00	0.00	0.00	1.17	2.20	3.02	3.71	4.29	5.42	6.25	6.90	7.43	8.23	8.82	9.27	9.64	9.95	10.21

ANNEX C

(*Clause* 6.3.3)

UCL AND *LCL* FOR CONTROL CHART ON NUMBER OF NON-CONFORMITIES

Non-conformities	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
		Number of Non-conformities 0(0.1)9.9								
0		1.05 0.00	1.54 0.00	1.94 0.00	2.30 0.00	2.62 0.00	2.92 0.00	3.21 0.00	3.48 0.00	3.75 0.00
1	4.00 0.00	4.25 0.00	4.49 0.00	4.72 0.00	4.95 0.00	5.17 0.00	5.39 0.00	5.61 0.00	5.82 0.00	6.04 0.00
2	6.24 0.00	6.45 0.00	6.65 0.00	6.85 0.00	7.05 0.00	7.24 0.00	7.44 0.00	7.65 0.00	7.82 0.00	8.01 0.00
3	8.20 0.00	8.38 0.00	8.57 0.00	8.75 0.00	8.93 0.00	9.11 0.00	9.29 0.00	9.47 0.00	9.65 0.00	9.82 0.00
4	10.00 0.00	10.17 0.00	10.35 0.00	10.52 0.00	10.69 0.00	10.86 0.00	11.03 0.00	11.20 0.00	11.37 0.00	11.54 0.00
5	11.71 0.00	11.87 0.00	12.04 0.00	12.21 0.00	12.37 0.00	12.54 0.00	12.70 0.00	12.86 0.00	13.02 0.00	13.19 0.00
6	13.35 0.00	13.51 0.00	13.67 0.00	13.83 0.00	13.99 0.00	14.15 0.00	14.31 0.00	14.47 0.00	14.62 0.00	14.78 0.00
7	14.94 0.00	15.09 0.00	15.25 0.00	15.41 0.00	15.56 0.00	15.72 0.00	15.87 0.00	16.02 0.00	16.18 0.00	16.33 0.00
8	16.49 0.00	16.64 0.00	16.79 0.00	16.94 0.00	17.09 0.00	17.25 0.00	17.40 0.00	17.55 0.00	17.70 0.00	17.85 0.00
9	18.00 0.00	18.15 0.05	18.30 0.10	18.45 0.15	18.60 0.20	18.75 0.25	18.90 0.30	19.04 0.36	19.19 0.41	19.34 0.46

Non-conformities	0	1	2	3	4	5	6	7	8	9
		Number of Non-conformities 10(1)9.9								
10	19.5 0.5	20.9 1.1	22.4 1.6	23.8 2.2	25.2 2.8	26.6 3.4	28.8 4.0	29.4 4.6	30.7 5.3	32.1 5.9
20	33.4 6.6	31.7 7.3	36.1 7.9	37.4 8.6	38.7 9.3	40.0 10.0	41.3 10.7	42.6 11.4	43.9 12.1	45.2 12.8
30	46.4 13.6	47.7 14.3	49.0 15.0	50.2 15.8	51.5 16.5	52.7 17.3	54.0 18.0	55.2 18.8	56.5 19.5	57.7 20.3
40	59.0 21.0	60.2 21.8	61.4 22.6	62.7 23.3	63.9 24.1	65.1 24.9	66.3 25.7	67.6 26.4	68.8 27.2	70.0 28.0
50	71.2 28.8	72.4 29.6	73.6 30.4	74.8 31.2	76.0 32.0	77.2 32.8	78.4 33.6	79.6 34.4	80.8 35.2	82.0 36.0
60	83.2 36.8	84.4 37.6	85.6 38.4	86.8 39.2	88.0 40.0	89.2 40.8	90.4 41.6	91.6 42.4	92.7 43.3	93.9 44.1
70	95.1 44.9	96.3 45.7	97.5 46.5	98.6 47.4	99.8 48.2	100.1 49.0	102.2 49.8	103.3 50.7	104.5 51.5	105.7 52.3
80	106.8 53.2	108.0 54.0	109.2 54.8	110.3 55.7	111.5 56.5	112.7 57.3	113.8 58.2	115.0 59.0	116.1 59.9	117.3 60.7
90	118.5 61.5	119.6 62.4	120.8 63.2	121.9 64.1	123.1 64.9	124.2 65.8	125.4 66.6	126.5 67.5	127.7 68.3	128.8 69.2

ANNEX D

(*Clause* 6.5.1)

CONTROL CHART DATA SHEET (ATTRIBUTES) — FORM 1 (NON-CONFORMING ITEMS)

Product:

Sheet No.:

Characteristic(s):

Sample size:

Frequency:

Period:

Production Order No.:

Workshop:

Machine No.:

Operator:

Inspector:

Sl No.	*Date*	*Time*	*Number Inspected*	*Number Non-conforming Items*	*Fraction/ Percent Non-conforming Items*	*Control Limits*		*Remarks*
						Upper	Lower	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)

Total:

Average:

CONTROL CHART DATA SHEET (ATTRIBUTES) — FORM 2 (NON-CONFORMITIES)

Product: Production Order No.:

Sheet No.: Workshop:

Characteristic(s): Machine No.:

Sample size: Operator:

Frequency: Inspector:

Period:

Sl No.	*Date*	*Time*	*Number Inspected*	*Number of Various Types of Non-conformities*					*Total No. of Non-conformities*	*Remarks*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Total:										
Average:										

ANNEX E

(Foreword)

COMMITTEE COMPOSITION

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